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ABSTRACT

This paper describes tests conducted on six different kinds of ice hockey helmets and discusses the safety factors in each. (JD)

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IMPACT CHARACTERISTICS OF ICE HOCKEY HELMETS

by

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In response to media and public alarm concerning the number of reported deaths in ice hockey, the Canadian Standards Association, in 1973, publised a standard for the manufacture of ice hockey helmets. For CSA approval, the helmet must be subjected to three impacts, of 20 foot-pounds each, at several locations on the helmet. This is done by fitting the helmet onto a polyurethane head form and striking it with a 10 pound wooden block dropped from a height of 2 feet. The average value of the transmitted force at each point is not to exceed 1500 pounds and no single force reading shall exceed 1850 pounds at any temperature between $-18^{0}C$ and $+23^{0}C$ (CSA 1973).

(Slide 1) While the CSA standard has led to many advances in head protection in ice hockey, there are no data concerning the performance characteristics of CSA approved helmets with respect to each other. This study was conducted, therefore, in an attempt to assess some of those characteristics.

Methodology

Sample

Three specimens of each of six CSA approved ice hockey helmets models were used. All were purchased from local sporting goods dealers and no helmet was ever worn under playing conditions prior to the testing.

Apparatus (Slide 2)

The test apparatus consisted of a size 7 1/4 NOCSAE-WSU type headform mounted on a tube carriage with provision for clamping in a number of positions. The carriage and headform assembly was raised and lowered by an electronically controlled winch. A spring release mechanism held the carriage in position and when released the headform assembly fell under gravity down two guide wires to strike a rigid anvil which was covered with a 13 mm thick, 50-durometer hardness rubber pad and rested on a 250 pound bed plate.

(Slide 3) A triaxial accelerometer, located at the c of g of the headform was used to detect deceleration in the a-p (Dx), lateral (Dy) and s-i (Dz) directions. The accelerometer output was passed to a signal conditioner and then to an analogue circuit where the resultant deceleration was computed. The resultant analogue signal was then passed to a two channel storage oscilloscope which was triggered externally.

Test Procedures (Slide 4)

The helmet to be tested was positioned on the headform and the chin strap secured. Two successive drops were conducted from a height of .6 m within a period of 60 seconds. The initial drop was used to condition the helmet and headform and to ensure that the helmet was properly fitted to the headform. Data was recorded from the second

drop.

All helmets were tested at the FB, RB and RS locations. The order of helmet testing was randomized but all tests were completed in one position before testing in the next position was started. All tests were conducted at room temperature of 21°C.

Data (Slide 5)

Two curves were displayed on the oscilloscope. One was the resultant deceleration time curve and the other was the deceleration time curve recorded from the dominant direction of the drop. This was included in order to facilitate the recording of time measurements.

From these traces measures of resultant peak voltage, time to peak voltage and total impact time were taken directly from the oscilloscope. The resultant peak voltage measure was converted to resultant peak deceleration (hereafter referred to as peak deceleration) and then both the average rate of peak deceleration and the Gadd Severity Index were calculated. The GSI was approximated by assuming a triangular wave form and using the equation $GSI = 2/7\ a^{2.5}t$; where a is the peak deceleration and t is the total impulse time.

Results

Test-retest results of peak deceleration made at the FB and RB locations produced a Pearson product moment

correlation coefficient of r = .98, thereby establishing the reliability of the test procedures.

Peak Deceleration and Average Rate of Peak Deceleration (Slide 6)

Means and standard deviations for peak deceleration, average rate of peak deceleration and GSI were calculated.

Peak decelerations ranged from 69 to 123 g. In treating this data, each test location was considered to be a separate factor and one way ANOVA revealed significant differences between helmets at each test position. (Sig = .001)

As well, the peak deceleration attained within any given helmet model was not uniform. No attempt was made to analyse this within performance statistically. However, it is obvious that some regions of a helmet do provide better protection than others.

G.S.I. Values of GSI ranged from 164 to 544 all below the critical level of 1000 considered by Gadd to be the threshold of danger to life and the 1500 level used in the NOCSAE football helmet standard.

(Slide 7) The average rate of peak deceleration was included as a measure which incorporates both time and peak deceleration. Values of this ranged from 12 to 27g/msec. One way ANOVA revealed significant differences between helmets at each test location. (Sig=.001) By and large these differences paralled those found for peak deceleration.

Discussion

Performance differences between models have been identified at each of three test locations using the measure of peak deceleration. In most instances better protection is afforded on the side and rear locations than on the front. This may have evolved from the fact that many of the deaths in ice hockey resulted from impacts to the side or back of the head and manufacturers responded by providing additional protection in these areas.

The GSI only provides an absolute threshold for head injury severity and does not provide any type of Scaling law for assessing head injury potential. Since the GSI results were all less than the critical value of 1000 none could be considered life threatening. This does not mean, however, that other forms of head injury would not be experienced. Furthermore the results do not mean that the helmets are totally safe. Rather, for impacts of about 3.4 m/sec (11 ft/sec) or less the helmets appear to provide reasonable protection.

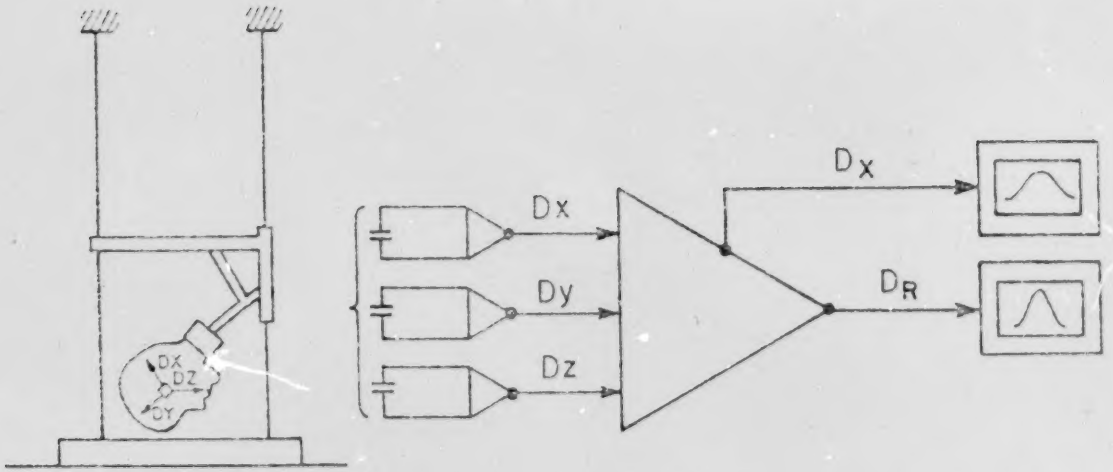
Thus, although the helmets tested in this study comply with the CSA standard, the measures of peak deceleration, average rate of peak deceleration and GSI confirm that helmet performance is not uniform between helmet models or within a given helmet model.

TABLE 1

HELMET CHARACTERISTICS

Helmet Number	Shell	Liner	Approximate Liner Thickness (in.)	Country of Manufacture	Other
1	One piece adjustable	High density Vinyl foam	.60"	Sweden	
2	Two piece adjustable	Polyfoam plus layer of open cell sizing foam	with sizer .80" without sizer .50"	Canada	
3	One piece non-adjustable	Polyfoam plus layer of open cell sizing foam	with sizer .90" without sizer .50"	U.S.A.	Liner pads are removable and come in several thicknesses
4	Two piece adjustable	Polyfoam	.50"	Canada	Foam material on outside on helmet at the side
5	One piece non-adjustable	Polyfoam plus layer of open cell sizing foam plus vinyl suspension	with sizer .95" without sizer .60"	Canada	
6	One piece non-adjusting	Ensolite foam	.65" - .75"	Canada	

SLIDE #1



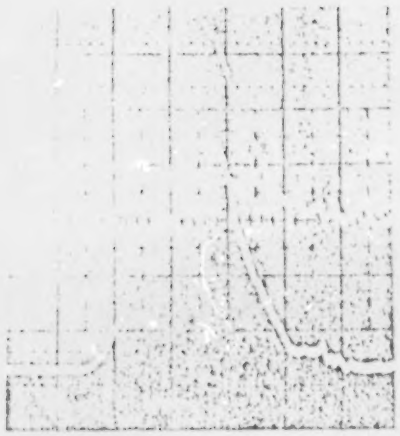
TEST RACK & TRIAX ACCELEROMETER

SIGNAL CONDITIONER

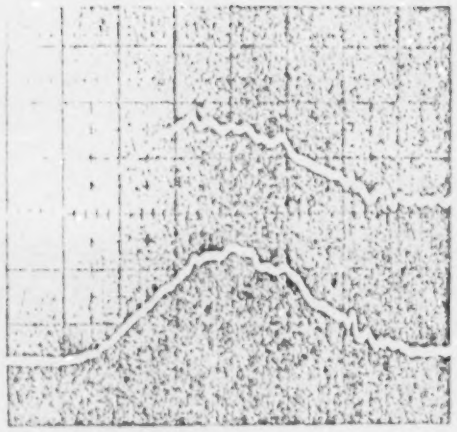
ANALOGUE CIRCUIT FOR CALCULATING RESULTANT

TWO CHANNEL STORAGE OSCILLOSCOPE

SLIDE #3



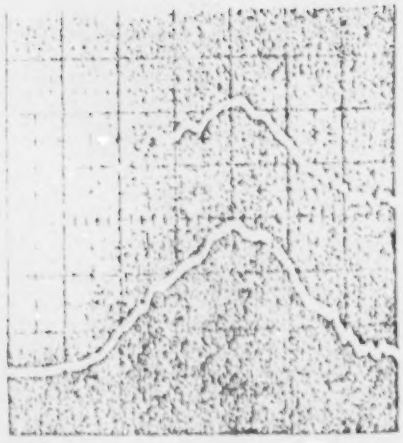
Helmet 1: RB
Sweep = 2 msec/div
Peak g = 125 g



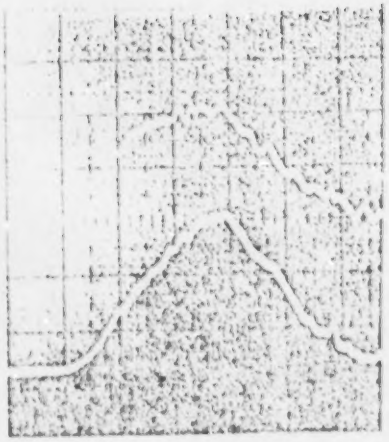
Helmet 2: RB
Sweep = 2 msec/div
Peak g = 67 g

Helmet 3: RB
Sweep = 2 msec/div
Peak g = 82 g

Helmet 6: RB
Sweep = 2 msec/div
Peak g = 90 g



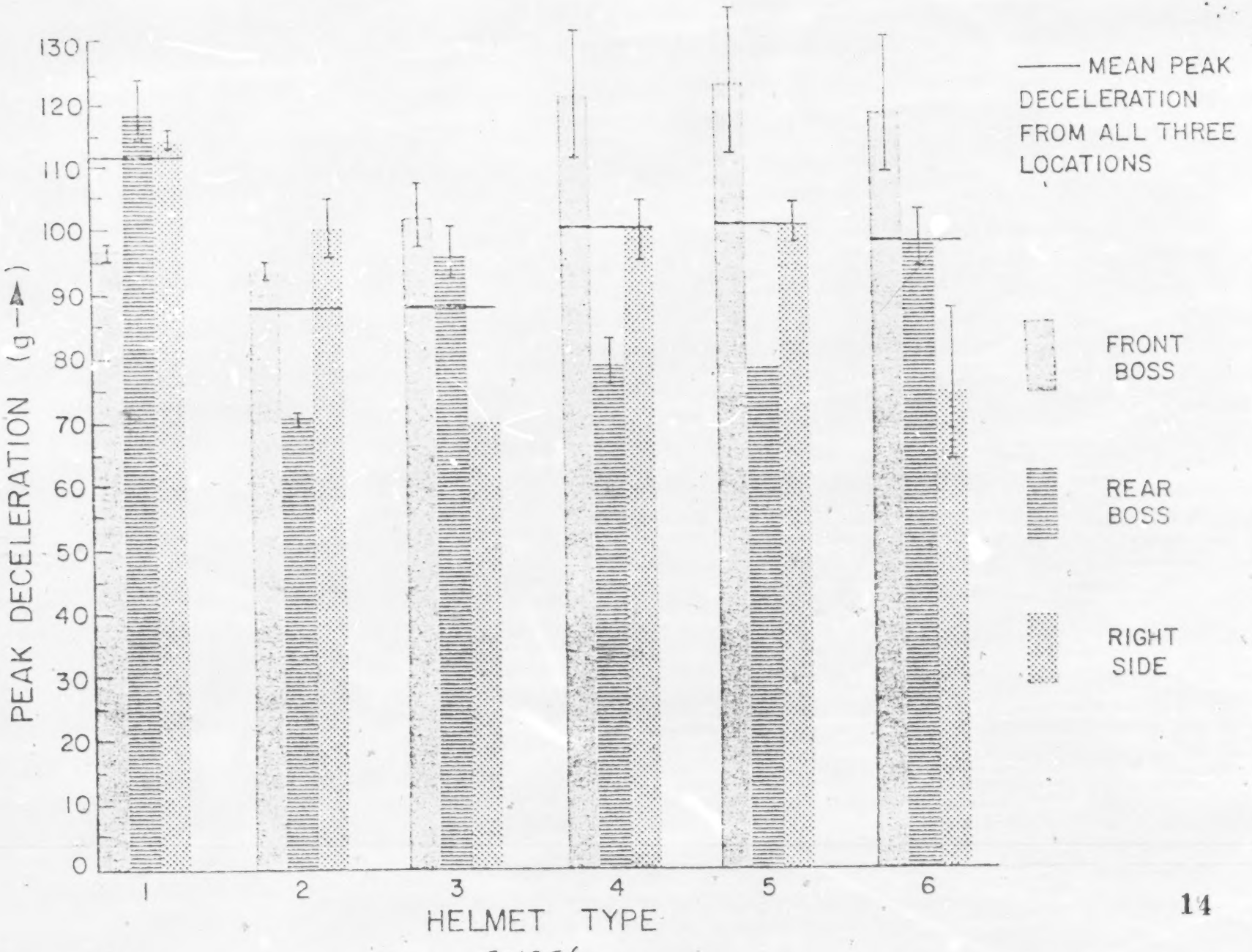
Helmet 4: RB
Sweep = 2 msec/div
Peak g = 79 g



Helmet 5: RB
Sweep = 2 msec/div
Peak g = 82 g

Deceleration-time traces at RB Location from .6m.
Upper trace is from dominant direction. Lower trace is resultant

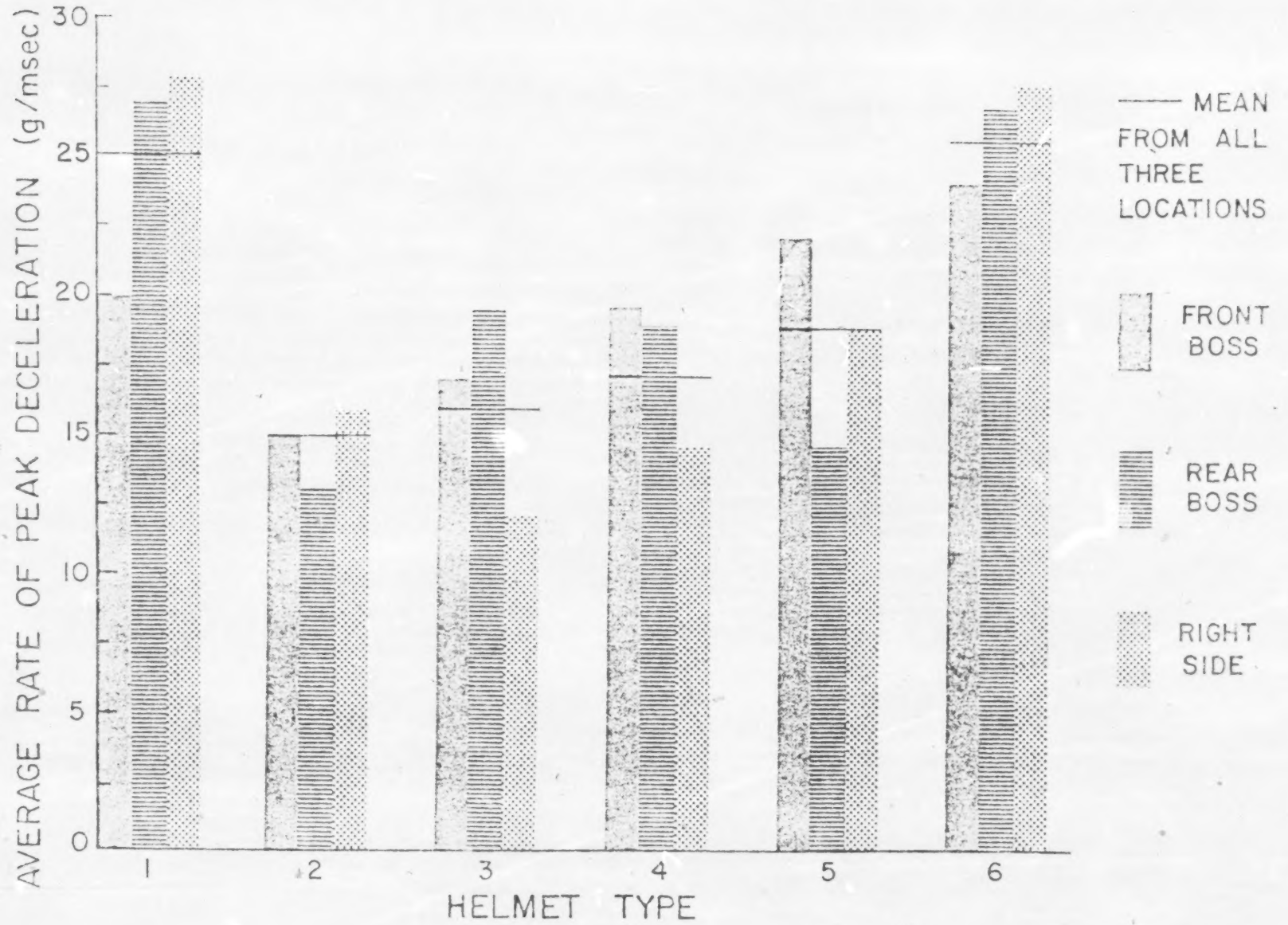
SLIDE 5


PEAK DECELERATION (g—▲)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
HELMET TYPE
MEAN PEAK DECELERATION FROM ALL THREE LOCATIONS
FRONT BOSS
REAR BOSS
RIGHT SIDE

13

SLIDE 6

14


AVERAGE RATE OF PEAK DECELERATION (g/msec)
30
25
20
15
10
5
0
1
2
3
4
5
6
HELMET TYPE
MEAN FROM ALL THREE LOCATIONS
FRONT BOSS
REAR BOSS
RIGHT SIDE

SLIDE 7